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Tunable Electronic Transport Properties of Metal-Cluster-Decorated III-V Nanowire Transistors

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ABSTRACT

In the past decade, III-V semiconductor nanowire (NW) materials such as InAs, InP, and InGaAs have attracted enormous research attentions due to their superior physical properties for next-generation electronics, sensors and photonics. In particular, single InAs NW field-effect transistors (FETs) have been demonstrated with extraordinary electron mobility in the range of 3000 to 10000 cm^2/Vs dependent on the NW diameter, and when configured in parallel array NW thin-film transistors (TFTs), they exhibit GHz device operation even fabricated on mechanically flexible substrates. However, majority of these III-V NW transistors are all functioned in the accumulation or depletion mode since the intrinsically high free carrier concentration in the NW channel is necessary to get depleted in order to achieve the device OFF-state. Here, we present a facile and reliable scheme to control the device operation by manipulating the threshold voltage (V_{TH}) of n-type III-V NWFETs via a metal cluster decoration approach, which is based on the work function difference between the metal clusters deposited and the NW materials to modulate the carrier concentration in the device channel. For the low work function metal clusters (i.e. Al), free carriers are donated from the clusters to the n-type channel such that the V_{TH} is negatively shifted for the D-mode NW transistors, whereas for the high work function metal clusters (i.e. Au), free electrons are withdrawn from the n-type channel to positively move the V_{TH} to obtain E-mode NW devices. More importantly, the versatility of our approach has been demonstrated through the fabrication of high-mobility enhancement-mode InAs NW parallel FETs as well as the construction of low-power InAs NW inverters consisting of both depletion and enhancement mode transistors. All these indicate the technological potency of this metal cluster decoration approach for future low-power, high-performance nanoelectronics, sensors and their device fabrication.

KEYWORDS

III-V nanowires, field-effect transistors, threshold voltage modulation, metal decoration, enhancement mode, depletion mode, inverters